Reacting Flows

Fact Sheet

Pour cream into a cup of coffee, and the cream eddies and roils, slowly diffusing throughout the dark liquid. This simple act is illustrative of a complex physical phenomena called turbulent mixing.

In combustion, the turbulent mixing of fuel and oxygen brings molecules of each into close contact necessary for chemical reactions to occur. Understanding these reacting flows is key to improving the understanding of the processes that control combustion.

CRF researchers take a holistic approach to the problem, striving for a better understanding of the roles of both fluid dynamics and chemistry, coupling experiments and simulation, and integrating advances in combustion theory and modeling, diagnostics, combustion chemistry, and computational science. The long-term goal of Combustion Research Facility research in this area is the development of detailed predictive models that are applicable to practical combustion devices, such as engines and furnaces.

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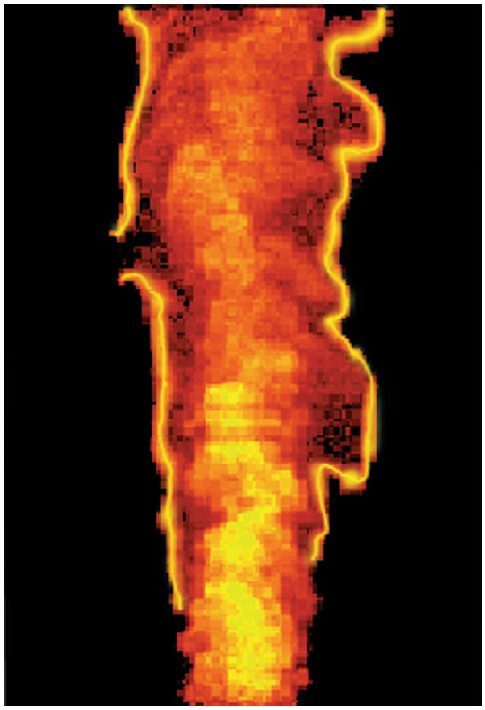
Research into the dynamic structure and chemistry of flames spans more than two decades at Sandia National Laboratories and is characterized by strong participation from outside collaborators. Researchers from experimental and theoretical backgrounds in multiple disciplines bring their expertise to bear on the problem using tools such as laser-based diagnostics, numerical simulations, and physical modeling approaches.



A planar image of methane and CH-radical concentrations in a turbulent non-premixed jet flame .

Three laboratories located at Sandia's Livermore, California, site are involved in fundamental turbulent combustion research:

Turbulent Diffusion Flame Laboratory

The CRF is an international leader in experimental research on the development and verification of statistical models for turbulent combustion due in part to this laboratory's capabilities for simultaneous measurement of temperature and chemical species concentrations in turbulent flames. Experiments are conducted on several turbulent reacting flows, including both premixed and nonpremixed flames, to better understand the fundamental processes of turbulent combustion and to provide detailed experimental data for validation of combustion models.

An array of nonintrusive laser diagnostics has been assembled in the Turbulent Diffusion Flame Laboratory that allows simultaneous measurement of temperature, major species concentration, and several minor species concentrations, including CO, OH, and NO, at a single spatial point. Many such measurements are collected at each of multiple flame locations to provide a unique quantitative data base for model validation.

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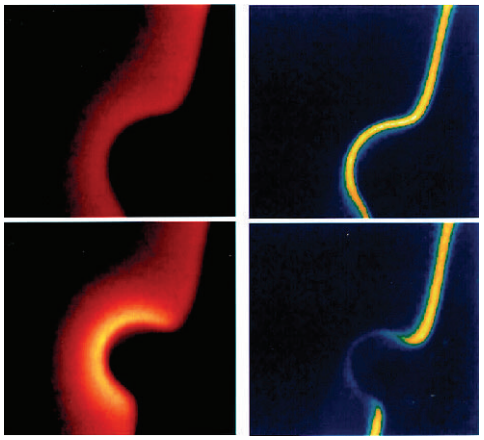
Because of the complexity of combustion events, researchers break the problem down into more manageable chunks. For example, a single flickering flame represents myriad chemical reactions taking place over time. The chemical species present, the temperature, and other properties of a particular spot in the flame at a particular point in time may change completely in the next instant. The challenge is understanding how all of these variables evolve over time and integrating these reaction "snapshots" into an accurate, overall picture.

A photograph of a piloted turbulent jet flame in the Turbulent Diffusion Flame Laboratory.

Turbulent Combustion Laboratory

This lab is the largest lab in the newly expanded CRF, and is really two labs in one. It provides a single location where a range of state-of-the-art diagnostics may be applied to fully characterize a given flame or burner configuration. These diagnostics are designed to extend all the capabilities of the Turbulent Diffusion Flame Lab to next-generation quantitative measurements along a line in the flame rather than just at one point. In addition, a second test stand in this lab will allow seeded flows for flow characterization and a broader range of imaging diagnostics and burner fuels.

The lab places a strong emphasis on collaborative interactions with visiting researchers. It is anticipated that many of those will arise out of the Turbulent Nonpremixed Flames Workshop, an annual international event that brings together experimental and computational researchers to compare combustion modeling approaches and experimental data, and to identify areas where further work is needed.



Planar laser-induced images of hydroxyl-radical (left pair) and CH-radical (right pair) concentrations in a premixed flame as it is being deformed (earlier time at the top) by a moving vortex of fluid.

Advanced Imaging Research Laboratory

This new lab is focused on the development of new imaging diagnostics and performing simultaneous imaging of multiple combustion species using up to six laser/camera systems. The lab houses three experiment stations to better accommodate collaborative interactions with visiting researchers. Data obtained in experiments in this lab are used to study fundamental subprocesses such as molecular mixing, unsteady response of chemical mechanisms, differential diffusion, and the effects of heat release on turbulence structure. Efforts are made to combine experimental projects with detailed simulations to validate chemical models and combustion submodels.

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